Before the
Federal Communications Commission
Washington, D.C. 20554

FCC 88-288
37462

In the Matter of	)	
	)	
Advanced Television Systems	)	
and Their Impact on the	)	
Existing Television Broadcast	)	
Service	)	
	)	
Review of Technical and	)	
Operational Requirements:	)	MM Docket No. 87-268
Part 73-E, Television Broadcast	)	
Stations	)	
	)	
Reevaluation of the UHF Television	)	
Channel and Distance Separation	)	
Requirements of Part 73 of the	)	
Commission's Rules	)	

TENTATIVE DECISION AND FURTHER NOTICE OF INQUIRY

Adopted: September 1, 1988 Released: September 1, 1988

By the Commission: Chairman Patrick issuing a statement; Commissioner Quello dissenting in part and issuing a statement at a later date; Commissioner Dennis issuing a separate statement.

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I. INTRODUCTION

1. This proceeding was instituted to address the technical, economic, legal, and policy issues presented by development of Advanced Television (ATV)[1] techniques utilizing new methods of signal transmission that may be employed to deliver programs with significantly improved video and audio quality.[2] The action we take today is an important step toward reaching the goal of authorizing terrestrial broadcast facilities[3] that will deliver to the public television pictures with clarity and color approaching that of 35 mm film and sound equivalent to that of compact discs. The primary focus of this proceeding is the initiation of broadcast ATV service. Among the various video distribution media, broadcast television is unique in that it is governed by a complex and interrelated set of both spectrum management and compatibility rules. Nevertheless, because non-broadcast media also are pervasive, we will take account of these media in evaluating our options regarding broadcast television.

2. The prospect of ATV provides great promise, but also presents significant challenge to the broadcast industry and its competitors, to the American electronics and manufacturing industries, and to our traditional broadcast regulatory scheme and associated spectrum management policies. The challenge facing the industry and this Commission is to design and implement a framework for the next generation of broadcasting that will promote efficient realization and wide dissemination of the benefits of this new technology, yet also will permit incorporation of future technological improvements in a timely and efficient manner.

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1 Within the category "ATV" we include any system that results in improved television audio and video quality, whether the methods employed improve the existing NTSC transmission system or constitute an entirely new system, see NOI at ¶ 19. Although terminology varies slightly within the industry, the new systems commonly are referred to either as High Definition Television (HDTV) or Enhanced Definition Television (EDTV). HDTV generally refers to systems that provide quality approaching that of 35 mm film, whereas EDTV refers to systems that perform better than NTSC but not on a par with 35 mm film.

2 Advanced Television Systems, Notice of Inquiry, MM Docket 87-268, 2 FCC Rcd 5125 (1987) (NOI).

3 For the purpose of this Further Notice the terms "broadcasting" and "broadcast service" refer to terrestrial television service provided within the existing VHF and UHF broadcast television allocations.

3. In the NOI, after describing the existing NTSC[4] transmission system and known ATV system proposals, we requested comment on the difficult and complex issues we must consider in determining whether the public interest will be served by authorizing VHF and UHF broadcast licensees to use ATV transmission techniques, and if so, the regulatory framework that should govern their use. We addressed issues related to the technological feasibility of using spectrum presently allocated for VHF and UHF broadcasting and the availability of additional suitable spectrum; the costs and benefits of utilizing ATV techniques in the VHF and UHF broadcast services and compatibility between ATV transmissions and NTSC receivers; and public policy issues related to competing demands for spectrum and ensuring uninterrupted service during transition from the NTSC system to either an ATV system or a mixed NTSC and ATV environment.

4. In this Tentative Decision and Further Notice of Inquiry (Further Notice) we begin the process of narrowing the issues related to the introduction of terrestrial broadcast ATV service by ordering our priorities and making several tentative findings as follows.

1. We find that providing for terrestrial broadcast use of ATV techniques would benefit the public.

2. We tentatively conclude that the benefits of this technology can be realized by the public most quickly if existing broadcasters are permitted to implement ATV.

3. We also tentatively conclude that any spectrum capacity needed for broadcast ATV system will be obtained from the spectrum now allocated to broadcast television. In the interests of efficient use of the spectrum and minimization of disruption to other services, we do not intend to consider the use of any frequency bands not already allocated for television terrestrial broadcasting.

4. We find that existing service to viewers utilizing NTSC receivers must be continued irrespective of the actual manner in which ATV services are delivered, at least during a transition period. This can be accomplished either by

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4 NTSC is the acronym for the National Television System Committee, an industry committee convened first in 1940 to establish technical standards for the broadcast television system and again in 1950 to establish color television standards.

transmitting ATV signals that can be received directly by NTSC receivers or by simulcasting NTSC and incompatible ATV signals on separate channels.[5]

5. Our strong predisposition to require NTSC receiver compatibility and the scarcity of suitable spectrum within the existing allocations lead us to conclude that systems requiring more than 6 MHz to broadcast a noncompatible signal, such as the MUSE HDTV 9 MHz system, will not be authorized for terrestrial broadcast service.

6. We find it in the public interest not to retard the independent introduction of ATV in other services or on non-broadcast media, but we are sensitive to the benefits of compatibility between equipment associated with the various video delivery methods.

5. The record in the first phase of this proceeding, including the comments filed by parties and the detailed substantive information developed by the Planning Subcommittee of the Advisory Committee on Advanced Television Service and the Advisory Committee's Interim Report,[6] has been of significant assistance in narrowing the issues and focusing debate on the issues related to possible authorization of ATV broadcast service. In addition to the subjects addressed in the tentative decision portion of this Further Notice summarized above, we also seek comment on and analysis of a number of additional related issues in the notice of inquiry portion.[7]

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5 The term "compatibility" is defined in the NOI at ¶ 80 to indicate that an ATV signal can be received on conventional NTSC reception equipment without additional hardware with quality not significantly degraded from that displayed when a conventional NTSC signal is received. In this Further Notice we continue to use "compatibility" in this sense. We note that Working Party 1 of the Advisory Committee's Planning Subcommittee defined the attributes of compatibility, see Advisory Committee, Planning Subcommittee Working Party 1 Attributes/Systems Matrix, Document PS/WP1-30 (undated).

6 See ¶¶ 10-14, infra.

7 MST, NAB, and NCTA filed a "Request for Setting Additional Comment Dates with Reply Comments" on January 19, 1988, requesting that we establish additional specific dates for comments as information on ATV becomes available. As this Further Notice indicates, we will provide for additional comment within the framework of existing procedures as we move towards decisions on the issues presented. Given the uncertain timetable of developments, we believe that moving forward with this Docket in response to events and decisions, rather than setting a rigid timetable, is the preferable method of proceeding. Therefore we will deny this request.

1. We seek comment on the issues, recommendations, and conclusions expressed by the Advisory Committee in its Interim Report.

2. We seek additional information on ATV systems being designed for terrestrial broadcast service,[8] including the feasibility of their operating under the interference limitations indicated by studies of the VHF and UHF spectrum.[9]

3. Within the existing allocations, we believe that our options to accommodate ATV are: (a) provide ATV within existing 6 MHz assignments; (b) provide to each broadcaster an additional 3 MHz for an augmentation signal; or (c) provide to each broadcaster an additional 6 MHz for either an augmentation signal or for a dual non-compatible ATV signal. We are particularly interested in comment on the advantages and disadvantages of these options.

4. We also seek additional comment on how standards should be established for ATV and whether we should relax or repeal the NTSC standard.

5. We intend to conclude our assessment of various spectrum options expeditously and, if we conclude that the spectrum associated with each allotment can and should be increased, to propose plans for that purpose. Therefore we request comment on possible scenarios for distributing supplemental spectrum if it is decided to do so, including allotment and assignment procedures we should follow.

6. Finally, we also request comment on adjustments we could authorize to permit licensees to negotiate with each other regarding their service areas in order to encourage the prompt and efficient introduction of ATV.

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8 A brief description of existing systems is at ¶¶ 22-37, infra.

9 See ¶¶ 54-72, infra.

II. BACKGROUND

A. Procedural History

6. To obtain information and develop a record upon which to make decisions related to the possible introduction of ATV, in July, 1987 we adopted the NOI in response to petitions from MST[10] and 57 additional parties. At that time there existed only limited information about ATV, and thus we requested information on a wide range of topics related to possible implementation of some form of broadcast ATV service.[11] In response to the NOI we received 70 comments, 26 reply comments, and 3 petitions to file supplemental information. A list of the commenting parties is attached as Appendix A.

7. In conjunction with the NOI, we issued an order freezing new television station license applications and allotment requests in the 30 major cities in which we believed a broadcast spectrum shortage might exist if we approve an ATV system requiring more spectrum than the present 6 MHz per station.[12] Finally, in October we granted a Petition for Special Relief filed by the same parties that petitioned for issuance of the NOI, deciding to defer action on additional sharing between UHF television and private land mobile stations until the Interim Report is received and we have considered the information presented after opportunity for public comment.[13]

8. We established the Advisory Committee in November, 1987 to gather and study information and make recommendations on ATV relevant to the difficult technical, economic, and public interest determinations that we must make.[14] The Advisory Committee is composed of industry leaders representing

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10 Appendix A to this Further Notice lists all parties participating in this proceeding and indicates the abbreviations used to refer to these parties.

11 See ¶ 3, supra.

12 Advanced Television Systems and Their Impact on the Existing Television Service, Order, RM-5811 (Mimeo No. 4074 released July 17, 1987).

13 Further Sharing of the UHF Land Mobile Radio Service, Order, 2 FCC Rcd 6441 (1987).

14 Formation of Advisory Committee on Advanced Television Service and Announcement of First Meeting, 52 Fed. Reg. 38523 (1987).

diverse viewpoints, including those of the television broadcast networks and stations, equipment manufacturers, cable systems, and the communications bar. The focus of the Committee's first six months has been to plan for the actual testing and evaluation of ATV systems, to evaluate the need for and availability of additional spectrum, and to assess the economic costs and benefits of introducing ATV.

9. At this stage approximately 175 participants have contributed to the work of the Subcommittees and Working Parties created to accomplish these tasks. The Committee has benefited from the cooperation extended by the Advanced Television Systems Committee (ATSC)[15] and expects to benefit similarly from cooperation with the newly-formed Advanced Television Test Center (ATTC).[16] On June 16, 1988, the Advisory Committee submitted an Interim Report to the Commission, discussed below. We have placed in the record of this proceeding the following documents from the Advisory Committee: a copy of the Advisory Committee Interim Report and associated comments by Advisory Committee members, the reports of the 6 working parties and 2 advisory groups of the Planning Subcommittee, and the Chairmen's summaries of these reports. Additional studies conducted by the Commission's Office of Engineering and Technology (OET) on spectrum availability and the NTSC UHF taboos also have been completed and placed in the record.[17] Thus there exists a substantial record upon which our tentative decisions and further inquiry are based.

B. Advisory Committee Interim Report

10. On June 16, 1988, the Advisory Committee submitted an Interim Report containing recommendations on the fundamental parameters and spectrum

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15 The Advanced Television Service Committee (ATSC) was formed in 1983 by the television industry to coordinate and develop voluntary national technical standards for ATV systems. The ATSC Charter specifies that it also will develop recommended positions for U.S. use in international standards organizations and consider submission of proposed voluntary standards, where appropriate, to this agency and to the American National Standards Institute (ANSI). See Remarks of E. William Henry to the Steering Committee of the FCC Advisory Committee on Advanced Television Service (March 10, 1988), a copy of which has been placed in the docket files of this proceeding.

16 The Advanced Television Test Center (ATTC) was established in 1988 by NAB, Cap.Cities/ABC, NBC, CBS, PBS, MST and INTS to test ATV systems.

17 Appendix B lists all reports, articles, and other statements that the Commission has placed in the record of this proceeding. Parties are invited to comment on the information contained in these additional documents.

requirements for ATV. The attributes and spectrum requirements of proposed ATV systems and the planned future work of the Advisory Committee are discussed in the Interim Report. The Advisory Committee concludes in the Interim Report that to remain competitive, broadcasters must have the opportunity to deliver HDTV-quality signals to their audiences, and that therefore efforts should be focused on establishing an HDTV standard for terrestrial broadcasting. The Advisory Committee states in the Report that at the present stage of technical development, channels of more than 6 MHz are necessary to transmit HDTV signals competitive in quality to those that will be offered by the non-broadcast media, and that therefore efforts also should be focused on determining the availability of spectrum.

11. The Advisory Committee categorized the spectrum requirements of systems designed to operate below 1 GHz as being 6 MHz, 9 MHz, or 12 MHz, and noted that 12 MHz systems may consist of either an existing NTSC-compatible channel supplemented by another 6 MHz that is not necessarily contiguous with the main channel, or an existing NTSC channel and another 6 MHz used to simulcast ATV programming. The Advisory Committee recommended that consideration be given the burdens that would be placed upon the broadcast, cable, and other industries that retransmit broadcast signals by any system that would require more than the existing 6 MHz.[18]

12. Although the Advisory Committee did not rule out the possibility that consumers may accept enhanced or improved picture and audio quality that is somewhat less than that of true HDTV, which it equated to the quality of 35 mm film, it suggested that systems resulting in less improvement be considered as solutions that might facilitate the transition from NTSC to HDTV.[19] The Advisory Committee also concluded that for the immediate future it is essential that any broadcast system be compatible with NTSC because of the substantial public investment in existing NTSC receivers. The Advisory Committee noted that many of the proposed systems would achieve compatibility either by augmenting NTSC signals or by simulcasting a non-compatible ATV channel with an NTSC channel.

13. The Advisory Committee stated that the long-term implications of the options may be significantly different from those of the short term, and urged that the different considerations over different time periods be considered carefully. For example, it noted that a 9 MHz non-contiguous system compatible with NTSC receivers is more spectrum efficient for the short term than a 12 MHz system that transmits a 6 MHz non-compatible ATV signal and a standard NTSC signal on a separate 6 MHz channel, thereby occupying a total of 12 MHz. However, the long-term spectrum implications may be the opposite,

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18 Interim Report at 6, fn. 3.

19 Id. at 5-7.

because the simulcast 6 MHz NTSC channel may be discontinued when ATV achieves significant market penetration. The spectrum thus released then would be available for another broadcast channel or for other purposes.[20]

14. The Advisory Committee concluded that sufficient spectrum capacity might be available within the existing VHF/UHF allocations for either the augmentation or simulcast approach, provided that (1) all the UHF "taboos" can be disregarded in the ATV environment, and (2) ATV systems can successfully operate with co-channel and adjacent channel interference protection that is less than that required by NTSC operation. The Advisory Committee stated that additional spectrum outside the existing broadcast allocations will have to be considered if these two conditions cannot be met.[21] The Advisory Committee also stated that no attempt should be made to retard the introduction of ATV by other non-broadcast means (such as by videocassette recorder or cable) while the necessary studies and analyses proceed, but recognized that problems may arise if the introduction of equipment for these other media result in the establishment of a de facto transmission standard that is not conducive to broadcast transmission. In order to accommodate the possibly different transmission standards of different media, the Committee suggested that attention be focused on development of inexpensive interfaces or receivers capable of accommodating different reception standards.

C. International Developments

15. In Europe, broadcasters plan to deliver HDTV-quality service by satellite rather than by terrestrial broadcasting.[22] The planned system will be incompatible with the PAL[23] and SECAM[24] terrestrial systems now used and terrestrial broadcast standards will remain the same. The HDTV system is

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20 Id. at 7.

21 Id. at 8.

22 See Eureka 95, The Road to High Definition Television (pamphlet, 1987). A copy is in the docket file.

23 PAL is the acronym for Phase Alteration Lines. A system in which the phase of the color burst subcarrier inverts in adjacent scanning lines. It is used in approximately 58 countries worldwide, with slight variations between countries.

24 SECAM is the acronym for Sequential Color with Memory. SECAM defines the parameters of the horizontal and vertical scanning rate and the frequency distribution of the visual, aural and color information within a TV channel. It is used in France, the USSR and approximately 21 other countries, with slight variations between countries.

designed to be compatible with a first generation European DBS system based upon a multiplexed analog component (MAC) design. Therefore in Europe it will be necessary to purchase both a satellite receiving antenna and a receiver dedicated to this type of reception. In some countries the satellite signals also may be carried on cable systems, but the consumer still will have to purchase a special receiver to view the signals with HDTV quality.

16. In Japan, the Ministry of Post and Telecommunications has decided to provide HDTV-quality service by satellite and also to provide for improved terrestrial service using an NTSC-compatible system that delivers better quality than the existing NTSC system but less quality than the satellite-delivered HDTV service. The HDTV satellite service is scheduled to be implemented in 1990 using the MUSE HDTV 9 MHz system[25] while inauguration of the first generation of improved terrestrial service is expected in 1989.[26]

17. BTA, a voluntary organization established in Japan by broadcasters and equipment manufacturers in cooperation with the Japanese Ministry of Posts and Telecommunications, plans to select an improved system to be used for terrestrial broadcasting. The new terrestrial broadcast standard will be limited to 6 MHz in bandwidth, and will be compatible with the existing NTSC system.[27] Ten different techniques are being considered,[28] and BTA states that it is tentatively planning to develop two generations so that future technological advances will be incorporated by Japan's terrestrial broadcasting services. The first generation of improved terrestrial service is expected to be inaugurated in 1989.[29]

18. BTA states that it expects the coexistence of different terrestrial and satellite systems to spur additional development of television improvements.[30] The first generation is intended to improve picture quality

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25 Matsushita Comments at 10. MUSE is the acronym for "Multiple Sub-Nyquist Encoding", the process by which the 22 MHz baseband NHK studio signal is compressed into 8.1 MHz for transmission in a 9 MHz channel. See NHK Comments at 2.

26 Toshiba Comments at 1.

27 Japan Satellite Comments at 2.

28 See Nippon Comments for a detailed discussion of the ten techniques being considered by the BTA.

29 Toshiba Comments at 1.

30 BTA is a standards setting organization for broadcasting in Japan. BTA Comments at 3.

by combining several enhancement methods, but not change the aspect ratio. BTA states that second generation will further improve picture quality by increasing the aspect ratio and other facets. BTA notes that some of the systems proposed in the United States are similar to the systems under consideration in Japan, and concludes that a common system could be developed for both countries.[31]

19. NHK suggests that a system could be used to facilitate transition from NTSC to ATV, and notes that it has developed a family of ATV systems based upon MUSE technology that it argues could be used for an orderly transition from NTSC to HDTV in the United States.[32] According to NHK, stations could provide a gradual transition to MUSE HDTV by adopting the NTSC-compatible MUSE system referred to as MUSE-6 because production and transmission equipment will be compatible between MUSE-6 and MUSE HDTV. NHK states that MUSE-6 can be employed within the existing 6 MHZ channels, and that if 3 MHz of contiguous spectrum is allocated later, only the encoder, transmitter and transmission lines would have to be changed to implement full MUSE HDTV.[33] NHK stresses, however, that MUSE-6 performance is significantly inferior to that of MUSE HDTV.[34] Sarnoff points out that its ACTV system as well as the MUSE family provide a transitional mechanism to HDTV.[35]

20. Thus it appears that both Japan and European nations are planning to provide ATV services, although implementation plans differ. While the European approach does not contemplate improvements to terrestrial broadcasting, the Japanese plans provide for making improvements to terrestrial broadcasting by implementing an improved NTSC system.

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31 BTA Reply Comments at 6-7.

32 NHK Comments at 12.

33 The spectrum studies conducted by the Advisory Committee's Planning Subcommittee Working Party 3 indicate that provision of additional spectrum to stations for ATV is facilitated if contiguous spectrum is not required. Interim Report at 18.

34 NHK Comments at 16. Sony goes further, stating that even the best of contemporary bandwidth reduction techniques cannot allow a representative HDTV picture portrayal via a single 6 MHz channel, and consider 8 to 9 MHz to be necessary to provide HDTV. Sony Reply Comments at ii.

35 Sarnoff Comments at 6.

21. Also, there has been considerable discussion within the CCIR,[36] the United States, and other countries concerning international agreement on a single world-wide HDTV production standard. Within the United States, the Advanced Television Systems Committee (ATSC) and the Society of Motion Picture and Television Engineers (SMPTE) have approved as a voluntary HDTV production standard an interlaced scanning standard based upon 1125 lines and 60 fields per second. Several European countries have proposed a progressive scanning system based upon 1250 lines and 50 fields per second. While national and international efforts at production standardization are outside the scope of this proceeding and indeed outside of our jurisdiction, in considering the various proposed ATV systems the availability of programs and their compatibility with various production standards are relevant to the overall quality and likely success of specific systems. Converting from a production source to a transmission source introduces a number of factors that might result in certain systems producing better results with one or another of the available program sources, and this is relevant to our consideration of the systems. Therefore we solicit information on the program signal formats that are to be utilized by the various system proponents. In addition, we request comment on the compatibility of the various systems with 35 mm film standards, the proposed 1125/60 standard, the European 1250/50 proposal, and any additional production standards.

D. Proposed ATV Systems[37]

1. Introduction

22. A number of organizations are planning to test and evaluate systems proposed for terrestrial use in the United States. It is anticipated that the Advisory Committee will conduct tests in cooperation with ATSC and ATTC to evaluate systems of those that voluntarily cooperate, and will report the test results and recommendations to the Commission and the public. The Advisory Committee and other industry groups plan not only to evaluate the technical performance of the individual systems, but also to conduct analyses to determine the level of quality and associated cost that is most acceptable to the public. The Advisory Committee's Systems Subcommittee has requested detailed technical descriptions and will conduct laboratory and field testing

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36 CCIR is the acronym for the International Radio Consultative Committee, an organ of the ITU that studies technical and operational questions relating specifically to radiocommunications. Discussion on HDTV has been centered in the CCIR Television Study group.

37 This discussion is based on comments received in this proceeding, the reports of the Advisory Committee, and trade press articles.

of the proposed systems. NCTA also is planning to test the suitability of ATV systems for cable delivery. Cooperation among these organizations may lead to industry consensus on the attributes of the system or systems most suitable for terrestrial broadcast purposes. The systems known to us to be under development are briefly discussed below. A number of different techniques are being developed to improve NTSC, to transmit high-quality video and audio within the existing 6 MHz channels, and to transmit improved signals using greater bandwidth.

2. NTSC-Compatible Systems

23. Several techniques have been proposed to improve the images displayed by NTSC that would not require an increase in bandwidth or significant change in the NTSC standard. There also are several systems that use a significantly altered NTSC standard but remain compatible with existing NTSC receivers. (Technical terms used in this section and elsewhere in this Further Notice are defined in Appendix C.)

24. According to Hitachi, its system uses progressive scanning and an aspect ratio of 4:3. "Three dimensional" luminance and chrominance filters are used in receivers that have frame store capability to provide progressive scanning. Hitachi states that this method is used to reduce cross color and cross luminance artifacts and to increase resolution. Hitachi states that it has found a method to utilize spectrum within a standard 6 MHz NTSC signal to increase chrominance and high-resolution luminance information.[38]

25. Matsushita states that its proposed system, QUME, produces widescreen images with greater resolution and reduced artifacts. Matsushita states that QUME adds extra information to the NTSC signal by modulating the detail and 16:9 aspect ratio information in quadrature with the video carrier. According to Matsushita, this design creates 1 MHz of additional bandwidth within the standard NTSC signal in which detail information can be transmitted without interference to other signal components that form the composite NTSC signal.[39] Although their system uses 6 MHz, Matsushita argues that broadcasters should be alloted additional spectrum so that performance can be improved to as close to that of MUSE HDTV as possible.[40]

26. Nippon states that it is experimenting with several techniques. One technique it describes to obtain a high resolution image is to divide the detail signal transmitted between 4.2 MHz and 5.6 MHz into blocks that

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38 Hitachi Comments at 2-4.

39 Matsushita Comments at Appendix 1.

40 Matsushita Comments at ii.

are transmitted with information indicating the priority of each block. According to Nippon, once priority has been assigned, quality images can be transmitted efficiently with only 5-10 percent of the entire detail block.[41]

27. Techniques for improving NTSC performance have been developed by Faroudja Laboratories and are now being marketed in the United States under the trade name SuperNTSC. Equipment reported to be available includes encoders, decoders, vertical and horizontal detail processors, flesh tone correctors, and transcoders. These products have been marketed for studio use, and broadcast and cable demonstrations using Faroudja equipment have been presented.[42] The system is intended to diminish cross color and other undesirable products.[43]

28. A number of systems are being developed to deliver improved performance to special receivers, yet continue to deliver NTSC quality service to conventional receivers. These systems use either 6, 9, or 12 MHz.[44] Among the single-channel proponents is the Del Rey Group.[45] Their system, named HD-NTSC, uses a subsampling technique to compress a high definition image to 6 MHz yet maintain NTSC receiver compatibility. Del Rey's "tri-scan" technique divides each picture element into three subpixels, each of which is transmitted in turn in each successive frame. The system slows the frame rate to ten per second for stationary objects, but keeps the NTSC frame rate of thirty per second for objects in motion, thereby increasing bandwidth efficiency. The aspect ratio is increased to 14:9, although Del Rey's comments state that 5:3 may be possible. Progressive scanning is used at the receiver, and the system is equipped with digital audio. In comparision to NTSC, HD-NTSC receivers are expected to display improved resolution for stationary objects (spatial resolution). However the resolution of moving objects (temporal resolution) will be slightly degraded relative to NTSC.

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41 Nippon Comments at 4.

42 Broadcasting, April 18, 1988, at 49, and Communications Daily, June 7, 1988, at 4.

43 Faroudja techniques are described in 96 SMPTE Journal 750-761 (No. 8, Aug. 1987).

44 Although it has not commented in this proceeding nor developed a complete system, we understand that High Resolution Sciences (HRS) has developed methods for improving the quality and resolution of NTSC.

45 This technical description is based upon that attached to Del Rey's Comments.

29. Schreiber[46] describes a 6 MHz NTSC compatible system that has been developed by the Massachusetts Institute of Technology (MIT) called MIT-RC (Receiver Compatible).[47] MIT-RC uses a portion of the height of the NTSC frame to enhance resolution signals. As described by Schreiber, digital audio and enhanced color through subsampling are possible additions to the signal.

30. Two ATV systems have been proposed that are NTSC compatible and would be transmitted within a 6 MHz channel, but both are designed to provide even better performance if supplemental spectrum is available. The David Sarnoff Laboratories' system, Advanced Compatible Television (ACTV), is being developed in two formats.[48] The 6 MHz version, ACTV I, compresses higher resolution, widescreen images into a 6 MHz channel while maintaining compatibility with NTSC receivers. The system uses subcarriers modulated in quadrature to provide extra information for increasing resolution and for constructing the side panels needed to obtain a 5:3 aspect ratio on ACTV receivers. ACTV I may use either 1050 line interlace or 525 line progressive scanning. A different system named ACTV II would deliver improved video resolution and digital sound comparable to that of compact discs. It would require an additional 3 or 6 MHz, not necessarily contiguous.

31. In addition to the MUSE HDTV system discussed above, NHK also is developing an NTSC compatible system, MUSE-6, that could be implemented initially on one channel and upgraded if extra spectrum becomes available.[49] MUSE-9 requires a 3 MHz supplemental channel that is not necessarily contiguous to the main channel.

32. There are two proposed systems that maintain compatibility with existing NTSC receivers but require additional spectrum. One, VISTA, developed by the New York Institute of Technology (NYIT), produces improved resolution and widescreen images.[50] VISTA is transmitted using one NTSC channel and either a 3 MHz or 6 MHz supplemental channel that does not have to be contiguous. To achieve compatibility, the NTSC portion of the signal is unaltered. Enhancement information is transmitted on the supplemental channel to improve spatial and temporal resolution. The frame-rate for transmission of the detail information is lower than normal to conserve bandwidth because

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46 Dr. William Schreiber, a professor at the Massachusetts Institute of Technology, is Director of MIT's Advanced Television Research Program.

47 Schreiber Comments at 4.2-7.

48 For technical description see Sarnoff Comments at Appendix A.

49 NHK Comments at 9-15.

50 A technical description is included in the NYIT Comments at Appendix.

human vision requires a longer time period to perceive high quality motion rendition.

33. Another proposed system that uses additional spectrum but maintains receiver compatibility is being developed by North American Philips (NA Philips).[51] Their system, called HDNTSC, was introduced as a 12 MHz system, but now could use 9 MHz.[52] The baseband HDNTSC information is packaged in two signals: the first is the NTSC signal, which is transmitted according to existing standards; the second contains additional information and is transmitted on a supplemental channel that does not have to be contiguous. The additional information includes the side-panels to extend the NTSC aspect ratio to 16:9, information to increase spatial and temporal resolution, pan-and-scan capability,[53] and digital multi-channel sound. NA Philips states that the NTSC portion of the signal can be modulated in the conventional analog manner and the supplemental signal could be digital, thereby making the system more flexibile with respect to interference constraints.[54]

3. NTSC-Incompatible Systems

34. Systems that are incompatible with NTSC and that can be transmitted in a single 6 MHz channel also have been proposed. One developed by Schreiber is called MIT-BE (Bandwidth Efficient).[55] MIT-BE is part of a family of 6 MHz ATV systems (the other member is MIT-RC, described above) in which channel utilization efficiency is increased by using double-sideband quadrature modulation and eliminating the sound carrier and retrace intervals. A frame store and additional signal processing is required at the receiver. Provision is made for limited data transmission and digital audio.

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51 For a technical description see A.G. Toth, M. Tsinberg, C.W. Rhodes, NTSC Compatible HDTV System, IEEE Transactions on Consumer Electronics (Feb. 1988).

52 This change in spectrum requirement is noted by NA Philips in a letter to Advisory Committee chairman Richard Wiley, May 26, 1988, at 10. The letter was submitted by NA Philips as a comment on the draft Interim Report, and is included with the Advisory Committee materials in the docket file of this proceeding.

53 "Pan and scan" refers to selecting the relevant portion of the wide aspect ratio image for display on NTSC receivers.

54 The possible extent of the constraints are the subject of the Advisory Committee Interim Report and the OET studies, discussed below at ¶¶ 54-72.

55 Shreiber Comments at 4.2-7.

35. NHK also has developed an additional compressed version of MUSE called Narrow-MUSE that can be transmitted in a single 6 MHz channel.[56] While this system does not perform as well as MUSE HDTV, NHK states that Narrow-MUSE does perform better than either of the NTSC compatible MUSE systems. Narrow-MUSE has been demonstrated by computer simulation.

36. Three systems that are designed for satellite delivery of ATV are NA Philips HDMAC-60, Scientific Atlanta HDB-MAC, and MUSE HDTV. None of these systems are compatible with NTSC. The Philips and Scientific Atlanta systems are multiplex analog component (MAC) systems using time division mutiplexing. This improves the separation of luminance and chrominance components over that of NTSC, reducing artifacts caused by combining these components in a single composite signal. NA Philips envisages its system being used to deliver programming to terrestrial broadcast stations, cable system headends, or directly to viewers' homes by DBS.[57] Scientific Atlanta's system is a High Definition version of its B-MAC DBS delivery system. B-MAC currently is being used to deliver programming by satellite.[58] MUSE HDTV is a bandwidth compressed version of the NHK studio standard.[59] Using this MUSE system, luminance and color difference signals are band-limited and then sampled. Quality losses due to compression are compensated for by receiver technology, including frame stores and devices that detect motion and take advantage of the eye's limited ability to resolve temporal resolution.[60]

4. Additional Systems

37. There are additional systems proposed that have technical parameters not known to us. A-Vision, Production Services, Inc., General Instrument Corporation, Avelex, Zenith, Viento Laboratories, Inc., and Osborne state that technical specifications for their ATV systems will be submitted to Working

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56 NHK Comments at 15.

57 NA Philips at 33.

58 For technical description, see ATSC, HDB-MAC A New Proposal For High Definition TV Transmission (Committee Document T3/147, Dec. 15, 1987).

59 See discussion of the studio standard at ¶ 21, supra.

60 This system is described in Ninomiya, Ohtsuka, and Izumi, A Single Channel HDTV Broadcast System - The MUSE (NHK Laboratories Note 304, September 1984).

Party 1 of the Advisory Committee's Systems Subcommittee.[61] In addition, three parties have proposed video and audio enhancement techniques that could be used as components of ATV systems: Quanticon (QUANTV), Digideck, and Dolby. Quanticon has patented a number of video enhancement techniques. Dolby and Digideck each propose audio subsystems. According to MST, two system proponents, AT&T Bell Labs and CBS, have withdrawn from research into ATV systems.[62]

E. Alternatives to VHF/UHF Broadcasting

38. In the NOI, we requested that parties compare the advantages and disadvantages of using the broadcast spectrum and services to transmit ATV-quality signals with using other existing services and spectrum, such as the Direct Broadcast Satellite Service (DBS), Multichannel Multipoint Distribution Service (MMDS), or an entirely new "ATV" service. We also requested comment on the costs and benefits of using spectrum to deliver high quality video programming to the public compared to relying upon methods that do not use spectrum, such as VCRs, videodisc players, and cable.

39. On the basis of the comments received, we conclude that broadcast stations provide services unique in the array of entertainment and non-entertainment programs freely available to the American public. Unlike many other countries, the United States has a strong and independent system of privately-owned and operated broadcast stations that transmit local and regional news, information, and entertainment as well as national and international programs. Therefore, initiating an advanced television system within the existing framework of local broadcasting will uniquely benefit the public and may be necessary to preserve the benefits of the existing system. Also, we believe that the benefits of these new technological developments will be made available to the public in the quickest and most efficacious manner if existing broadcasters are permitted to implement ATV. We emphasize that this decision does not foreclose provision of ATV services by other means, both those that use spectrum and those that do not. Thus, we conclude that broadcasters should be permitted to utilize ATV transmission techniques within the existing VHF and UHF bands to the extent that this use can be accommodated and that continued broadcast service to the public is not disrupted, including service to those viewers with NTSC standard receivers.

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61 Advisory Committee, Systems Subcommittee Working Party 1, Document No. SS/WP1-014.

62 MST Comments at Appendix A.

III. SPECTRUM ISSUES

A. Introduction

40. In this section we consider the possibilities for providing additional spectrum to implement ATV service. In particular, we address the requirements of the various proponent ATV systems, the advantages and disadvantages of the options, and the region of the spectrum best suited for supplemental allotments. Most parties agree that the technical quality of broadcast signals increases with bandwidth, but the quality desired by the public and the "optimum" quality, given the complex tradeoffs, are far from certain.

B. Spectrum Availability

1. Positions of the Parties

41. The commenting parties generally discuss three possible spectrum requirements for terrestrial ATV systems in the VHF and UHF bands: (a) 6 MHz (one present channel), (b) 9 MHz (one and one-half present channels), or (c) 12 MHz (two present channels). Two of the 6 MHz systems are reported to have the capability of using an additional 3 MHz to attain additional enhancement if it is available. Of the systems proposing to use 9 MHz, some do not require that the additional 3 MHz be contiguous to the main channel. Advocates of a 12 MHz approach suggest that the additional 6 MHz could be used either (1) to supplement the main channel by providing additional information that would be integrated with the main signal at the receiver, or (2) to simulcast an ATV signal with the NTSC signal.[63]

42. Most broadcasters state that it is too early to decide whether 6 MHz is enough bandwidth to support ATV service of sufficient quality to compete with the full HDTV quality that might be delivered by other media, and argue that additional testing is necessary before a decision can be made on bandwidth. Cap. Cities/ABC argues that existing knowledge is insufficient to determine the bandwidth necessary to provide competitive quality, and concludes that before bandwidth decisions are made more knowledge is needed on the technical possibilities and the likely response of the public to degrees of change in aspect ratio, resolution, and other characteristics.[64]

43. MST points out that NHK, NA Philips, and NYIT all have developed systems based on the position that it is not possible to deliver within 6

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63 Proposed ATV systems are discussed at ¶¶ 22-37, supra.

64 Cap. Cities/ABC Comments at 4.

MHz a signal compatible with NTSC receivers with true HDTV quality. MST argues that additional spectrum should be preserved to permit terrestrial ATV compatible with existing NTSC receivers to develop. MST states that not to plan for additional spectrum capacity may foreclose systems that will be compatible with existing receivers, significantly increase the cost to consumers by requiring the use of spectrum with poorer propagation or more expensive receivers, or totally preclude terrestrial broadcasters from delivering ATV.[65] Similarly, NBC, which expresses support for the Sarnoff ACTV system, states that even if 6 MHz proves adequate, the Commission still should reserve additional spectrum for broadcasters so that future technological improvements can be implemented.[66]

44. According to NHK, there is little probability that a system will be developed soon that has the quality of its 9 MHz HDTV MUSE, is NTSC compatible, and can be transmitted within 6 MHz.[67] Matsushita agrees that it does not expect successful development of a 6 MHz "HDTV quality" system.[68] Similarly, Toshiba states that there is "little chance" that bandwidth can be reduced to 6 MHz.[69] Home Box Office, a cable network owned by Time, also states that 6 MHz may not be enough bandwidth to deliver signals of the desired quality.[70] However, Zenith states that history and experience suggest that improved technology eventually might result in a 6 MHz system that produces fully acceptable picture quality, and recalls that at one time creating a color television standard compatible with monochrome seemed impossible.[71] Also, LMCC argues that requiring ATV systems to operate within

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65 MST Comments at 34. MST and LMCC filed supplemental information that includes studies performed by the Media Laboratory at the Massachusetts Institute of Technology and the Committee for the North American HDTV Demonstrations to the Public that address the degree of technical quality that consumers desire. We will accept these late-filed comments, as well as those of MAET.

66 NBC Comments at 11.

67 NHK Comments at 21.

68 Matsushita Comments at 6.

69 Toshiba at 1.

70 Time Comments at attachment p. 5, High Definition Television: An Opportunity for Cable, by Home Box Office, Inc.

71 Zenith Comments at 5-6.

the existing 6 MHz channels will promote development of spectrum efficient transmission methods as well as permit improved broadcast signal quality.[72]

45. Time states that bandwidth greater than 6 MHz could cause severe technical problems for cable distribution of broadcast signals because greater bandwidth will require new cable converters that would add considerable complexity and cost to converters used by cable systems on customer premises and new equipment at cable headends. Also, Time argues, if broadcasters use more than 6 MHz, particularly if non-contiguous spectrum is used, there also may be significant problems with ghosting, airplane flutter, and harmonically related carriers used by cable systems to minimize interference. Finally, Time notes that cable systems have a large but finite bandwidth, that many systems today are operating at or near full capacity, that adding capacity is costly and that increasing signal bandwidth might result in cable operators dropping services in order to devote the additional bandwidth to each broadcast signal.[73]

46. Several parties argue against authorizing additional bandwidth because they prefer other uses of the spectrum. According to LMCC, adopting this course of action also will permit increased sharing of UHF channels to relieve "the critical and growing need for additional spectrum in the Private Land Mobile Radio Services."[74] Rogers also argues that any additional UHF broadcast spectrum available should be used for mobile radio and telephone purposes rather than ATV use, assuming equal consumer demand for the two services, because broadcast services can be received over cable by seventy percent of the population and functionally equivalent ATV services will be available with videocassette recorders, laser disc players, and satellite services, whereas there is no functional equivalent for mobile radio services.[75] CBS, however, states that sharing spectrum with land mobile services would cause significant degradation to existing television stations and that land mobile needs can be fulfilled with their existing allocations if they utilize spectrum-efficient technologies.[76]

47. RTT states that additional spectrum could be used for interactive video services through which viewers could communicate with their service

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72 LMCC Comments at 4.

73 Time Comments at 14.

74 LMCC Comments at 4.

75 Rogers Comments at 4.

76 CBS Comments at 53.

provider. According to RTT, its system, T-NET, permits two-way wireless transmission of data on channels adjacent to that of an operating station, permitting viewers to communicate using a keypad, a computer terminal, or a voice device for purposes of home shopping and banking, viewer surveys, educational functions, and general data communication.[77]

48. Neuman states that we must address the trade-off between signal quality and authorizing more diverse sources of programming at the present level of transmission quality.[78] Similarly, NBMC states that new opportunities for minority television ownership are available only in the UHF band, and argues that the public will suffer from a reduction in programming diversity if ATV prevents establishment of new minority owned television facilities.[79] However, CBS disagrees, and states that there would be little public benefit from additional television licensees if they were deprived of HDTV capability and therefore relegated to being providers of an inferior service.[80]

49. No party supports the option of obtaining a contiguous assignment by totally "repacking" the UHF and VHF spectrum into 9 MHz channels. MST states that partial or total repacking of the VHF and UHF band is an "extremely undesirable option" because it would be more costly and disruptive than justified by the possible benefits.[81] Sarnoff submits that total repacking would be difficult to implement, would make existing receivers obsolete, and would require several technical studies to determine whether repacking is even feasible.[82]

50. Several parties discuss the likely technical and economic ramifications that non-contiguous scenarios would entail for broadcasters and viewers. MST states that many experts believe that use of non-contiguous spectrum would create ghosting problems that could be difficult and costly, if not impossible, to correct.[83] Similarly, Blonder Tongue states that "in the

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77 RTT Comments at 3.

78 Neuman at 2.

79 NBMC Comments at 2.

80 CBS Comments at 54.

81 MST Comments at 37.

82 Sarnoff Comments at 14.

83 MST Comments at 42.

real world of ghosts, noise sources and atmospheric anomalies, non-contiguous frequencies, particularly if emanating from physically displaced antennas, may even drop the ATV picture quality below the level of a normal NTSC transmission."[84]

51. Additionally, NHK argues that use of multiple demodulators, if non-contiguous spectrum is used, would lower picture quality because of differences in the transmission and reception characteristics of the two channels.[85] Zenith concurs that use of non-contiguous supplemental spectrum probably would accentuate multi-path distortion and other transmission differences and thereby degrade picture quality. In addition, Zenith notes the extra cost to consumers for a separate tuner if augmentation spectrum is non-contiguous. Schreiber also states that non-contiguous spectrum is less likely to work properly under actual operating conditions than two contiguous channels.[86] Similarly, Matsushita agrees that differences in transmission characteristics between widely separated frequencies would restrict the system and lead to higher receiver cost.[87]

52. Based on the design of both the NYIT and NA Philips systems, MST states that signals transmitted on two non-contiguous frequencies could be integrated by a sophisticated receiver that automatically would select the second channel as directed by a digital code inserted in the vertical blanking interval of the NTSC channel. MST states that such a receiver probably would employ field stores to convert the NTSC portion of the signal from interlaced to progressive scanning.[88] NYIT states that initially its VISTA receivers would cost "slightly more" than large-screen projection displays.[89] NA Philips also states that its ATV receivers would be more expensive than current models.[90]

53. CBS expresses support for the simulcast option, noting that programming would not necessarily have to be the same on the NTSC and ATV

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84 Blonder Tongue Comments at 3.

85 NHK Comments at 21.

86 Schreiber Comments at 2-3.

87 Matsushita Comments at 11.

88 MST Comments at Appendix B, p. 7.

89 NYIT Comments at 13.

90 NA Philips Comments at 29.